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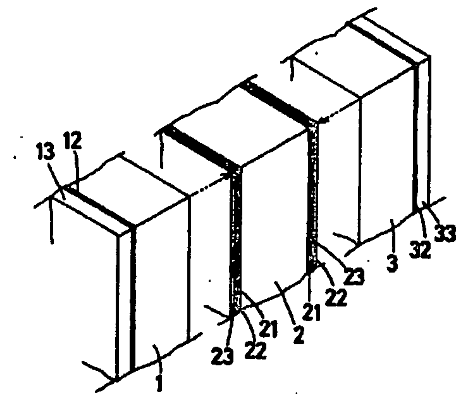
(54) PHOTOISOLATOR AND ITS MANUFACTURING METHOD

(57) Abstract

Purpose: To provide a photoisolator with a strong adhesive strength and good insertion loss and extinction ratio, even without using an optical adhesive, resin, and glass with a low melting point.

Solution means: In a photoisolator, a polarizer 1 and a photodetector 3 are respectively adhered to both surfaces of a Faraday rotor 2 on which metal oxide thin films 21, 22,

and 23 are coated, with the metal element constituting the metal oxide thin film 23 of the surface of the Faraday rotor 2 and the metal elements included in the polarizer 1 and the photodetector 3 interacting and being integrated.



CLAIMS

1. A photoisolator, characterized by the fact that a polarizer and a photodetector are respectively adhered to both surfaces of a Faraday rotor on which metal oxide thin films are coated; with the metal element constituting the metal oxide thin film of the surface of the Faraday rotor and the metal elements included in the polarizer and the photodetector interacting and being integrated.

2. The photoisolator of Claim 1, characterized by the fact that hydroxyl groups, which are respectively included in the metal element constituting said thin film of said Faraday rotor, and the metal elements included in said polarizer and said photodetector interacting via a water cluster.

3. The photoisolator of Claim 1, characterized by the fact that said polarizer and said photodetector are made of a polarizing glass or rutile monocrystals; with said thin films of said Faraday rotor being formed by a metal oxide monolayer or multilayer structure.

4. The photoisolator of Claim 3, characterized by the fact that said metal oxide is selected from Al_2O_3, TiO_2, and SiO_2.

5. A method for manufacturing a photoisolator, characterized by the fact that metal oxide thin films are coated on both surfaces of a Faraday rotor; with a polarizer and a photodetector respectively making contact with these two surfaces and heat-treated, so that the metal element constituting said thin film and the metal elements included in said polarizer and said photodetector interact and are integrated.

6. The method for manufacturing a photoisolator of Claim 5, characterized by the fact that in contacting said polarizer and said photodetector with said Faraday rotor, a treatment with an acid or water is carried out.

7. The method for manufacturing a photoisolator of Claim 5, characterized by the fact that the above-mentioned heat treatment is carried out at 200-300°C.

DETAILED EXPLANATION OF THE INVENTION

[0001]

TECHNICAL FIELD OF THE INVENTION

The present invention pertains to a photoisolator, which is used as an optical circuit part, transmits light forwards, and does not transmit light backwards, and its manufacturing method.

[0002]

PRIOR ART

In an optical communication system, light emitted from a semiconductor laser is projected on the end surface of an optical fiber via a lens and is transmitted; part of the light is reflected by the end surface of the optical fiber, returned to the semiconductor laser, and becomes noise. In order to remove the returned light, a photoisolator is used. The photoisolator consists of a polarizer, a Faraday rotor, and a photodetector.

[0003]

For example, in Japanese Kokai Patent Application No. Hei 6[1994]-75189, a photoisolator in which a polarizer, a Faraday rotor, and a photodetector are adhered and integrated using an optical adhesive and a resin is presented. Since the photoisolator adhered with adhesive, etc., had a poor moisture resistance and heat resistance and generated an emission gas, the optical axis of the photoisolator was shifted, or other optical parts were negatively affected. In Japanese Kokai Patent Application No. Hei 8[1996]-146351, a photoisolator in which parts

are adhered with a light-transmitting glass with a low melting point is presented. In the photoisolator using the glass with a low melting point, a reflectionless coat applied to suppress the insertion loss due to the difference in the refractive index of the polarizer or photodetector and the Faraday rotor was degraded, and when the polarizer and the photodetector were made of a polarizing glass, the polarizing glass was degraded.

[0004]

PROBLEMS TO BE SOLVED BY THE INVENTION

The present invention solves the above-mentioned problems, and its objective is to provide a photoisolator with a strong adhesive strength, good insertion loss and extinction ratio, and excellent optical characteristics, having no degradation of the optical surface, even without using an optical adhesive, resin, and glass with a low melting point.

[0005]

MEANS TO SOLVE THE PROBLEMS

In order to achieve the above-mentioned objective, in the photoisolator of the present invention, as shown in Figures 1 and 2 corresponding to an application example, a polarizer 1 and a photodetector 3 are respectively adhered to both surfaces of a Faraday rotor 2 on which metal oxide thin films 21, 22, and 23 are coated, with the metal element constituting the metal oxide thin film 23 of the surface of the Faraday rotor 2 and the metal elements included in the polarizer 1 and the photodetector 3 interacting and being integrated.

[0006]

In the photoisolator, hydroxyl groups, which are respectively included in the metal element constituting the thin film 23 of the Faraday rotor 2, and the metal elements included in the polarizer 1 and the photodetector 2 interact via a water cluster.

[0007]

If the material of the thin film 23 of the Faraday rotor 2 is SiO_2 and the material of the polarizer 1 is a polarizing glass containing SiO_2 as a component, the interaction is presumed to occur as follows. If water is adsorbed to Si of these materials, a Si-OH group is generated. As shown in Figure 3, the Si-OH group of the thin film 23 of the Faraday rotor 2 is hydrogen-bonded to the Si-OH group of the polarizer 1 via the water cluster 4, and the Faraday rotor 2 and the polarizer 1 are adhered to each other. Also, as shown in Figure 4, the Si-OH group of the thin film 23 of the Faraday rotor 2 and the Si-OH group of the polarizer 1 are directly hydrogen-bonded. The polarizing glass of the photodetector 3 also generates a similar hydrogen bond.

[0008]

The polarizer 1 is made of a polarizing glass or rutile YVO_4 monocrystals. On its surface, a reflectionless coat consisting of monolayer or multilayer thin films 12 and 13 selected from metal oxides of TiO_2 and SiO_2 may also be applied by the electron-beam vapor deposition method. The photodetector 3 is similar to the polarizer 1.

[0009]

The Faraday rotor 2 is made of a magneto-optical material such as garnet monocrystals. The thin films 21, 22, and 23 of both surfaces of the monocrystals have a monolayer or multilayer structure consisting of metal oxides. These metal oxides are preferably selected from Al_2O_3, TiO_2, and SiO_2. The thin films 21, 22, and 23 are formed by vapor-depositing these metal oxides at a thickness in which transmitted light becomes reflectionless by the electron-beam method.

[0010]

The method for manufacturing the photoisolator of the present invention is characterized by the fact that metal oxide thin films are coated on both surfaces of the Faraday rotor 2; the polarizer 1 and the photodetector 3 are respectively make contact with these two surfaces and are heat-treated, so that the metal element constituting the thin film 23 and the metal elements included in the polarizer 1 and the photodetector 3 interact and are integrated.

[0011]

With this heat treatment, a photoisolator, in which the metal element constituting the thin film 23 of the surface of the Faraday rotor 2 and the metal elements included in the polarizer 1 and the photodetector 3 interact and are integrated, is obtained.

[0012]

In this manufacturing method, when the polarizer 1 and the photodetector 3 make contact with the Faraday rotor 2, a washing treatment with an acid or water is applied. Preferably, the washing treatment is carried out with a solution of hydrochloric acid-hydrogen peroxide-pure water, a solution of sulfuric acid-hydrogen peroxide-pure water, and a solution of ammonia-hydrogen peroxide-pure water. With the washing treatment, since OH groups are uniformly attached to the metal elements included in the thin film 23 of the Faraday rotor 2, polarizer 1, and photodetector 3, the interaction is made easy.

[0013]

The conditions of the heat treatment after contacting the polarizer 1 and the photodetector 3 with the Faraday rotor 2 are 200-300°C, preferably 250°C, for 2 h. The photoisolator obtained under these conditions has an adhesive strength of 100 g/mm^2 or more. If the heat treatment is applied at a temperature higher than said temperature, the adhesive surface strength is increased. The reason for this is presumed as follows. When the polarizer 1 is a polarizing glass containing SiO_2 and the thin film 23 of the Faraday rotor 2 is a SiO_2 film, when the heat treatment is applied at 200°C or lower, the interaction between Si is mainly that of a hydrogen bond as shown in Figure 3, and the distance between the surfaces of the polarizer 1 and the thin film 23 of the Faraday rotor 2 is 0.7 nm. On the contrary, as the heat treatment conditions reach a high temperature of 700°C or lower, a hydrogen bond as shown in Figure 4 is mainly generated, and the distance between the surfaces is 0.35 nm.

[0014]

A micro-roughness of the surface that is greater than the distance between these surfaces, that is, a thickness irregularity of several μm and warp of several tens of μm seen on the entire surface of a mirror face, causes no problems in the adhesion, since the surfaces are elastically deformed.

[0015]

The photoisolator has good optical characteristics including an insertion loss of 0.3 dB or less and an extinction ratio of 35 dB or more. However, as the heat treatment conditions reach a high temperature, the strain due to the thermal expansion coefficient for each material is increased, so that the extinction ratio of the photoisolator is decreased.

[0016]

EMBODIMENT OF THE INVENTION

Next, an embodiment of the present invention is explained in detail by the figures.

[0017]

As shown in Figure 1, in the photoisolator of the present invention, a polarizer 1, a Faraday rotor 2, and a photodetector 3 are adhered to each other and integrated. The Faraday rotor 2 is made of garnet monocrystals. On both of its surfaces, Al_2O_3 film 21, TiO_2 film 22, and SiO_2 film 23 are sequentially vapor-deposited. The polarizer is made of a polarizing glass and includes SiO_2 as a glass component. A TiO_2 film 12 and a SiO_2 film 13 are vapor-deposited as a

reflectionless coat on one surface of the polarizer 1. The photodetector 3 has a constitution similar to that of the polarizer 1.

[0018]

Such a photoisolator is manufactured as follows. First, the polarizer 1, a Faraday rotor 2, and the photodetector 3 are washed with a solution of hydrochloric acid-hydrogen peroxide-pure water, a solution of sulfuric acid-hydrogen peroxide-pure water, and a solution of ammonia-hydrogen peroxide-pure water, in that order. The surface on which the thin films 12 and 13 are not formed in the polarizer 1 makes contact with one thin film 23 of the Faraday rotor 2, and the surface on which the thin films 32 and 33 are not formed in the photodetector 3 makes contact with the opposite surface of the Faraday rotor 2 and is heat-treated at 250°C for 2 h. With this treatment, Si constituting the thin film 23 of the surface of the Faraday rotor 2 and Si included in the materials of the polarizer 1 and the photodetector 3 interact and are integrated.

[0019]

Next, application examples to which the present invention is applied and comparative examples to which the present invention is not applied are explained in detail.

[0020]

APPLICATION EXAMPLE 1

The surfaces of garnet monocrystals were finished by a mirror-like polishing and cut to a shape of 15 mm x 15 mm and 0.5 mm in thickness. On both of its surfaces, three layers of Al_2O_3 film with a thickness of 80 nm, TiO_2 film with a thickness of 50 nm, and SiO_2 film with a thickness of 70 nm were sequentially formed by an electron-beam vapor deposition, so that a Faraday rotor was formed.

[0021]

The surface of polarizing glass was finished by the mirror-like polishing and cut to a shape of 15 mm x 15 mm and 0.5 mm in thickness. Two layers of TiO_2 film with a thickness of 50 nm and SiO_2 film with a thickness of 265 nm were formed on one of its surfaces by the electron-beam vapor deposition, so that a polarizer and a photodetector were formed.

[0022]

The polarizer, the Faraday rotor, and the photodetector were washed with a solution of hydrochloric acid:hydrogen peroxide:pure water of 1:1:5, a solution of sulfuric acid:hydrogen

peroxide:pure water of 1:1:5, and a solution of ammonia:hydrogen peroxide:pure water of 1:1:5, in that order, for 5 min each.

[0023]

The surfaces on which a reflectionless coat was not applied in the polarizer and the photodetector made contact with both surfaces of the Faraday rotor, and the optical axis was adjusted so that the extinction ratio reached a maximum at room temperature. It was heat-treated at 250°C for 2 h, cooled, and integrated. This was cut, so that a photoisolator with a shape of 2 mm x 2 mm was manufactured for trial.

[0024]

The adhesive strength of the photoisolator manufactured for trial was 136 g/mm^2. The insertion loss was 0.19 dB, and the extinction ratio was 37.7 dB. The insertion loss and the extinction ratio were measured at a wavelength of 1.31 μm. Furthermore, when the state of the adhered interface was observed by an optical microscope at a magnification of 400 times from the direction perpendicular to the adhered interface, the surface inside of all the samples was uniform.

[0025]

APPLICATION EXAMPLE 2

Similarly to Application Example 1 except for using rutile monocrystals in the polarizer and the photodetector, a photoisolator was manufactured for trial. The adhesive strength was 121 g/mm^2. The insertion loss was 0.25 dB, and the extinction ratio was 35.9 dB.

[0026]

COMPARATIVE EXAMPLE 1

Similarly to Application Example 1 except for washing with acetone and pure water for 5 min and changing the heat treatment conditions to three conditions of 200, 300, and 400°C for 2 h, three kinds of photoisolators were manufactured for trial. In all three kinds of photoisolators, the adhesive strength was only 28-33 g/mm^2, so a sufficient adhesive strength could not be obtained. The insertion loss was 0.18-0.19 dB, and the extinction ratio was 42.2-43.3 dB.

[0027]

COMPARATIVE EXAMPLE 2

Similarly to Application Example 1 except for setting the heat treatment temperature to 100°C, a photoisolator was manufactured for trial. Its adhesive strength was only 28 g/mm^2, so a sufficient adhesive strength could not be obtained.

[0028]

COMPARATIVE EXAMPLE 3

The washed polarizer, Faraday motor, and photodetector prepared in Application Example 1 were adhered with a light-transmitting glass having a low melting point. The glass with a low melting point had a refractive index of 1.51 at a wavelength of 1.31 μm. They were heat-treated at 350°C for 2 h, then adhered and fixed, so that a photoisolator with an adhesive strength of 620 g/mm^2 was manufactured for trial. However, the insertion loss was 1.8 dB, and the extinction ratio was 30.6 dB. When it was observed by an optical microscope at a magnification of 400 times, the roughness of the adhered interface was observed.

[0029]

As a result, in the photoisolator of the present invention, compared with photoisolators other than that of the present invention, the adhesive strength, the insertion loss, and the extinction ratio are good, and there is no degradation of the optical surface.

[0030]

EFFECTS OF THE INVENTION

As explained above in detail, the photoisolator of the present invention has a strong adhesive strength, little degradation of the optical surface, good insertion loss and extinction ratio, and excellent optical characteristics. According to the manufacturing method of the present invention, since no holder is required and an optical adhesive, resin, and glass with a low melting point are not used, the number of processes is small, and a photoisolator with a high reliability can be provided at a low cost.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is an oblique view showing an application example of the present invention.

Figure 2 is a partially enlarged diagram of the application example of the present invention.

Figure 3 explains the bonding state of a hydrogen bond.

Figure 4 explains another bonding state of a hydrogen bond.

EXPLANATION OF NUMERALS:

1	Polarizer
2	Faraday rotor
3	Photodetector
4	Water cluster
12, 22, 32	TiO_2 films
13, 23, 33	SiO_2 films
21	Al_2O_3 film

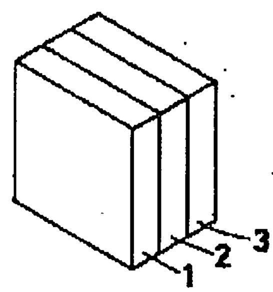


Figure 1

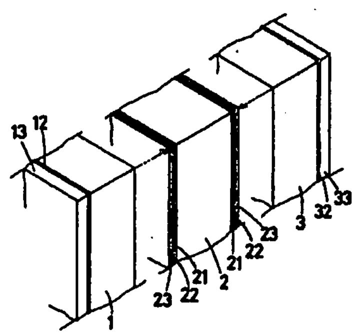


Figure 2

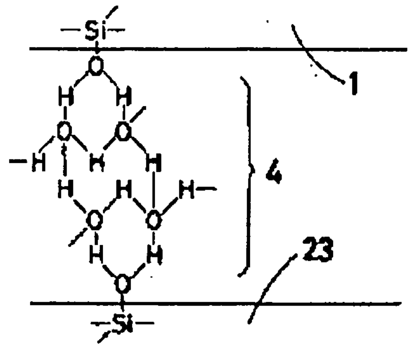


Figure 3

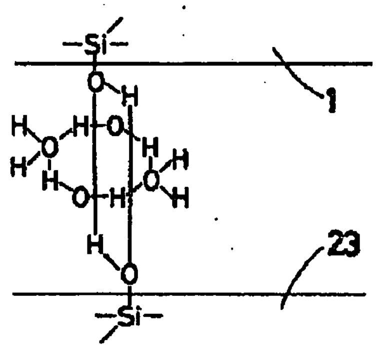


Figure 4